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Frequency and Correlates of Sleep Debt in St. Petersburg

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Abstract: Purpose During weekdays, many of us fail meeting their physiologic sleep need. During weekends, however, when given additional sleep opportunity, homeostatic sleep pressure will typically lead to longer bedtimes, manifesting the cumulative sleep debt. This study aims at examining the prevalence and determinants of sleep debt, as indicated by the presence of 2 h weekend bedtime prolongation, in a general population. Methods We studied 257 healthy subjects living in St. Petersburg, Russia. All participants indicated their habitual bedtimes during weekdays and weekends, and completed the Epworth Sleepiness Scale (ESS), Fatigue Severity Scale, Fatigue Impact Scale, Pittsburgh Sleep Quality Index, and Hospital Anxiety and Depression Scale. Results One-hundred-three participants (40%) exhibited a relevant sleep debt (2 h weekend–weekday difference in habitual bedtime). Compared to participants without sleep debt, the frequency of excessive daytime sleepiness (ESS score 11)—but not of fatigue, impaired sleep quality and mood disturbances—was higher in participants with sleep debt (21% vs. 10%, p = 0.01). Multiple regression analysis revealed younger age, higher ESS and lower body mass index as independent associates of sleep debt. Conclusions Sleep debt appeared to be very common among healthy subjects, and independently associated with younger age, higher ESS scores and lower BMI. However, the presence of sleep debt did not have an impact on fatigue or mood, as measured by validated questionnaires.

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Frequency and correlates of sleep debt in St. Petersburg

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Abstract

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Methods: We studied 257 healthy subjects living in St. Petersburg, Russia. All participants indicated their habitual bedtimes during weekdays and weekends, and completed the Epworth Sleepiness Scale (ESS), Fatigue Severity Scale, Fatigue Impact Scale, Pittsburgh Sleep Quality Index, and Hospital Anxiety and Depression Scale.

Results: One-hundred-three participants (40%) exhibited a relevant sleep debt (≥2h weekend-weekday difference in habitual bedtime). Compared to participants without sleep debt, the frequency of excessive daytime sleepiness (ESS score ≥11) – but not of fatigue, impaired sleep quality and mood disturbances – was higher in participants with sleep debt (21% vs. 10%, p=0.01). Multiple regression analysis revealed younger age, higher ESS and lower body mass index as independent associates of sleep debt.

Conclusions: Sleep debt appeared to be very common among healthy subjects, and independently associated with younger age, higher ESS scores and lower BMI. However, the presence of sleep debt did not have an impact on fatigue or mood, as measured by validated questionnaires.

Keywords: habitual bedrest duration, daytime sleepiness, chronic sleep restriction, social jetlag, validation

1. Introduction

In contrast to other brain functions, the mysterious yet vital biological function of sleep has only recently started to be disentangled. These advances also increased the awareness on the numerous detrimental effects of insufficient sleep, including higher metabolic and cardiovascular morbidity and mortality [1, 2], disturbed daytime vigilance with increased risk of car accidents and impaired work performance [3, 4]. Insufficient sleep is also associated with substantial economic burden [5]. Nevertheless, today sleep loss is so common in our 24/7 society that epidemiologists consider it a *public health epidemic* [6].

Experimental studies using carefully designed sleep extension or restriction protocols improved our knowledge on physiologic sleep need, including specific aspects in the homeostatic and circadian build-up of sleep pressure and the dynamics of recovery from sleep restriction [7]. These well-controlled in-laboratory studies demonstrated a near-linear deterioration in neurocognitive performance with continuing sleep deprivation, yet affected subjects often underestimated the cumulative cost of extended wakefulness [8, 9]. Subjective ratings of daytime sleepiness did not represent a reliable measure of the accumulated sleep pressure, and the discrepancy between subjective and objective measures of daytime sleepiness was largest in individuals with particularly short habitual sleep durations [10]. On the other hand, as shown by the work of Klerman and Dijk, shorter habitual bedrest duration was associated with a stronger increase in total sleep time during three consecutive days with 16h sleep opportunity [11]. In other words, sleep debt is more likely to reveal itself in the presence of extended sleep opportunities than by self-reported sleepiness, and the magnitude of weekend catch-up sleep might represent a useful approximation to the degree of sleep debt incurred during weekdays.

Despite being recognized as a pervasive public health concern, the prevalence of sleep debt in the general population remains unknown. The available epidemiologic studies are limited by the inevitable reliance on self-reported information, but also by varying approaches to measure sleep debt. Most population-based surveys on sleep habits simply provided the percentage of people with reported sleep times below 6h, or below the recommended 7-8h [12]. Others referred to sleep debt as the discrepancy between self-reported sleep and perceived sleep need [13-15], an approach that neglects the cumulative nature of sleep loss and the generally poor appreciation of one's physiologic sleep need. Weekend catch-up sleep, reflecting a direct homeostatic consequence of sleep debt, has been assessed in few studies, mostly in adolescents [16-18]. Of note, one of these studies confirmed the appropriateness of assessing weekend catch-up sleep by showing that poor performance on attention tasks was associated with increased weekend catch-up sleep but not with weekday sleep duration or subjective sleepiness [16].

Epidemiologic studies usually strive for maximal generalizability, and this comes at the cost of measurement precision. As a result, it appears that the Epworth Sleepiness Scale (ESS) has not yet been separately validated in subjects with and without sleep debt, despite being the most common cause of daytime sleepiness in society.

Hence, the primary goal of the present study was to characterize frequency and determinants of sleep debt in a general population sample. In addition, we also aimed at assessing the psychometric properties of the ESS in participants with and without sleep debt.

2. Participants and methods

The present study was conducted between June 2014 and October 2017 at the Department of Neurology and Psychiatry of the Almazov National Medical Research Centre, St. Petersburg, Russia. The Ethics Committee of the Saint Petersburg State University approved the study protocol (No. 44-2012), and written informed consent for study participation was obtained from all participants.

2.1 *Participants*

Data were extracted from a cohort of healthy people that had been selected to reflect a representative subset of the general population in St. Petersburg, with an adequate distribution of different age categories and educational status (defined as highest educational degree attained). The original intention was to use this cross-sectional cohort as control group for an ongoing project aiming at validating several self-reported scales in Russia [19, 20]. The participants included in the present study needed to have a complete data set as specified below. Notably, we excluded participants with previously diagnosed sleep-wake disturbances, including shift work. We did not include adolescents aged <18y, because habitual bedtime duration (HBD) during adolescence are instable due to changes in physiological sleep need and social influences. Most participants (n=214, 83%) completed the questionnaires during the months of February and March, when the lengths of day in St. Petersburg steadily increase from 8h to 13h. The city is located at 59.9° North latitude, at the Western end of the UTC+3 time zone. Besides age and sex, we obtained the following demographics: body mass index (BMI), marital status (single, married, or divorced), and education status, as determined by their highest education attainment (primary school degree; college school degree; university degree).

2.2 *Timing and duration of habitual bedrest, sleep debt, and social jetlag*

Separately for weekdays and weekends, participants indicated their habitual times when they used to go to bed in the evening and to get up in the morning. This allowed us to compute their HBD both during weekdays and during weekends, and to calculate the magnitude of HBD prolongation during weekends, reflecting the measure of sleep debt. Based on the habitual weekday and weekend evening bedtimes and morning getting up times, we inferred to what degree the participants delayed their bedrest timing during weekends. We also determined the magnitude of social jetlag, calculated as the difference in HBD mid-points between weekends and weekdays. The ratio between HBD and self-reported mean sleep times indicated the participants' subjective sleep efficiency.

2.3 *Self-administered questionnaires*

To assess subjective daytime sleepiness, we used the Russian version of the ESS. We described the process of translation and cultural adaptation in previous work [19]. The ESS is the most widely used self-report scale to indicate subjective sleep propensity [21]. Participants must rate on a scale of 0-3 their dozing probability in eight real-life situations. The total ESS score ranges from 0 to 24, with scores of ≥11 indicating subjective EDS. In addition to daytime sleepiness, we assessed various daytime symptoms that are known to be influenced by insufficient sleep, including fatigue and mood disturbances [22]. To this end, we administered two common self-administered fatigue scales, namely the Fatigue Severity Scale (FSS) and the Fatigue Impact Scale (FIS), to assess severity of fatigue and its cognitive, physical and psychosocial consequences in daily life. The Russian versions of FSS and FIS have been validated in patients with multiple sclerosis, myasthenia gravis, and healthy controls [19, 20]. Participants completed also the Hospital Anxiety and Depression Scale (HADS), which consists of two 7-item subscales assessing separately anxious and depressive symptoms [23]. Finally, we obtained information on subjective sleep quality by administering the Pittsburgh Sleep Quality Index (PSQI), which comprises 19 items, seven component scores (sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, sleeping medication, daytime dysfunction), and one global composite score [24].

2.4 *Reliability, validity and exploratory factor analyses of ESS*

We estimated the internal consistency of the ESS by Cronbach's alpha statistics and item-to-total correlations. Cronbach's alpha should preferably be around 0.8-0.9, with ≥0.7 regarded as "acceptable" by most researchers. We assessed ESS stability by asking 52 participants to complete the scale a second time after 3-4 weeks, using intraclass correlation coefficient as a measure of test-retest reliability. The percentage of lowest and highest possible scores showed the floor and ceiling effects of the ESS. Construct validity was assessed by comparing ESS scores between participants with relevant sleep debt (≥2h) and participants without sleep debt (≤1h). This so-called "known-group comparison" was based on the hypothesis that ESS scores would be higher in participants with relevant sleep debt, thereby revealing that the ESS measures the intended construct of sleep propensity. To further explore – without any preconceived hypothesis – the structural validity and factor structure of the ESS in participants with various degrees of sleep debt, we subjected their ESS data to exploratory factor analysis with principal components analysis and Varimax rotation. High Kaiser-Meyer-Olkin values established the sampling adequacy of the ESS. Next, we determined the number of factors by analyzing eigenvalues and primary factor loadings, in order to understand whether the ESS has the attribute of unidimensionality. We illustrated the factor structure of the ESS by a scree plot, and depicted the loadings of all eight ESS items as component plot in rotated space, in order to visualize the correlations between the first two factors.

2.5 *Statistical analysis*

Statistical analyses were done with SPSS version 25 (IBM, Armonk, New York, NY, USA). We used Student's *t*-test to compare normally distributed data between two groups, and applied chi-square test in case of nominal data. The Kolmogorov-Smirnov test was applied to verify whether data were normally distributed. We conducted correlation analyses of normally distributed data by means of Pearson's *r* coefficient. To identify independent associates of more pronounced sleep debt as well as higher ESS, we employed multiple linear regression models, including the following potential predictor variables: age, BMI, education status, HADS, FSS and PSQI. Significance was accepted at $p<0.05$.

3. Results

3.1 *General overview*

We included 257 participants, 90 males (35%) and 167 females (65%). Their mean age was 38.8±18.2y (range: 17-84y). Participants went to bed at 23:47±1h14min during weekdays, and at 00:35±1h34min during weekends. Habitual getting up time was 07:23±1h14min on weekdays, and 09:41±1h47min on weekends. HBD was 7.6±1.3h on weekdays and 9.1±1.2h on weekends. During weekdays, HBD was ≤7h in 97 participants (37.7%), and ≤6h in 37 participants (14.4%). Female participants appeared to have longer HBD than males, both on weekdays (7.8±1.3h vs. 7.4±1.3h, $p=0.03$) and on weekends (9.2±1.2h vs. 8.8±1.2h, $p=0.01$). The mean weekday-weekend discrepancy (i.e. sleep debt) was, however, remarkably similar between sexes (1.5±1.4h vs. 1.5±1.4h, $p=0.70$), as was the magnitude in social jetlag (1h29min±1h14min in females vs. 1h37min±1h14min in males, $p=0.41$). Moreover, during weekends female and male participants similarly delayed both their evening bedtime (45±63min vs. 54±69min, $p=0.29$) and morning getting up time (2h14min±1h43min vs. 2h25min±1h33min, $p=0.42$). With older age, HBD increased on weekdays ($r=0.202$, $p=0.001$) and decreased on weekends ($r=-0.138$, $p=0.03$), while the weekend delays became much shorter with respect to both evening bedtime ($r=-0.434$, $p<0.001$) and morning getting up time ($r=-0.546$, $p<0.001$). Likewise, age and social jetlag showed a similarly strong inverse correlation ($r=-0.554$, $p<0.001$).

3.2 *Prevalence and determinants of sleep debt*

In 103 participants (40%), HBD prolongation on weekends was ≥2h, suggesting relevant sleep debt. Relevant sleep debt was similarly prevalent in males and females (42.4% vs. 38.9%, p=0.35). Sleep debt significantly correlated with social jetlag (r=0.478, p<0.001). Specifically, sleep debt emerged mainly by earlier getting up times on weekdays and by delaying getting up times during weekends (**Fig 1A+B**); delayed evening bedtimes on weekend, on the other hand, did not correlate with sleep debt (r=-0.083, p=0.19). Weekday HBD showed a strong inverse correlation with the magnitude in sleep debt (r=-0.568, p<0.001). Participants with relevant sleep debt estimated their sleep efficiency higher than participants without relevant sleep debt (92.0±11.2% vs. 86.8±16.6%, p=0.004), but the groups similarly estimated their sleep latency (20.2±21.5min vs. 23.4±27.9min, p=0.31). In addition, participants with relevant sleep debt were younger, had a lower BMI, and were more likely to be single than those without sleep debt (**Table 1**). ESS scores were significantly higher in participants with than without relevant sleep debt, and their EDS frequency was more than doubled (21% vs. 10%, p=0.01). Multiple regression analysis confirmed younger age (t=-3.452, p<0.001), higher ESS scores (t=3.406, p<0.001) and lower BMI (t=-1.971, p=0.050) as independent associates of a more pronounced sleep debt (**Table S1**). **Fig 2** depicts the inverse correlation of age with both sleep debt (A) and social jetlag (B).

3.3 *Determinants of daytime sleepiness and fatigue*

The strongest correlation of ESS scores were found with sleep debt (r=0.249, p<0.001), followed by the delay of getting up time during weekend (r=0.197, p=0.001), habitual bedtime during weekdays (r=-0.174, p=0.005), and social jetlag (r=0.153, p=0.014). Sleepy participants had often also fatigue (63.2%) (**Fig 3A**). Participants with comorbid EDS-fatigue were more likely (p=0.01) to exhibit a relevant sleep debt (67%) than participants with isolated EDS (43%), isolated fatigue (35%), or no vigilance disturbance (38%) (**Fig 3B**). Despite the significant overlap between EDS and fatigue, sleep debt correlated only with ESS (r=0.249, p<0.001) but not with FSS scores (r=0.036, p=0.57). In a multiple regression model, sleep debt (t=3.402, p<0.001) was the strongest independent predictor of daytime sleepiness, followed by lower education status (t=-2.288, p=0.02) and higher anxiety levels (t=2.087, p=0.04) (**Table S1**).

3.4 *Reliability and exploratory factor analyses of the Epworth Sleepiness Scale*

Internal consistency of the ESS was nearly acceptable (Cronbach's alpha 0.69), with most items showing a moderate correlation to the total score (Pearson's r: 0.37-0.48), except for item 6 (r=0.28) and item 8 (r=0.23). When performing the reliability analysis in the subgroup with ≥2h HBD prolongation on weekends (n=103), Cronbach's alpha was 0.71. A large majority of 92% and 95% reported no chance of dozing in ESS items 6 and 8, respectively. Cronbach's alpha remained reasonably stable, if one item was deleted at a time (**Table 2**). Fifty-two participants completed the ESS twice within 3-4 weeks, and test-retest reliability appeared to be good (intraclass correlation coefficient: 0.75, p<0.001). The ESS showed marginal floor (2.3%) and no ceiling effects. Following extraction by principal component analysis, two components had eigenvalues >1.0, as illustrated by the scree plot in **Fig 4A**. The first two components explained only 32.9% and 18.2% of the total variance. A component plot in rotated space also suggested a two-factor solution, with items 6 and 8 clustering apart from the remaining ESS items (**Fig 4B**).

4. Discussion

We found that a large proportion (40%) of our cohort reported a ≥2h weekend increase in HBD, indicating a sleep debt incurred during weekdays. These participants were younger, sleepier, reported higher sleep efficiency, had lower BMI, spent less time in bed on weekdays, and showed a stronger social jetlag than participants without sleep debt. Greater sleep debt was the strongest predictor of higher ESS scores. Sleep debt was not associated with other daytime symptoms such as fatigue, anxiety or depression, but participants with comorbid sleepiness-fatigue had a higher likelihood to exhibit a relevant sleep debt compared to those with only sleepiness. While females had longer HBD on both weekdays and weekends, frequency and amount of sleep debt as well as social jetlag were similar between sexes.

The high frequency (40%) of ≥2h weekend recovery sleep in our sample is in line with other observations – obtained with different methodological approaches – regarding the pervasiveness of chronic sleep restriction in modern society [25]. In a 2003 US survey, 35-40% of adults reported sleeping less than the usually recommended 7-8h on weekday nights, and about 15% reported sleeping less than 6h. In a later cross-sectional population-based survey on sleep duration among 110,441 US adults of ≥18y age, 28.3% reported to sleep ≤6h [26]. Over the last 50 years, the percentage of the population reporting <6h of sleep per night increased tenfold, from 3% to 30% [27]. Short habitual bedtime durations were also common in our sample – 37.7% of participants spent ≤7h, and 14.4% ≤6h in bed. Comparison between studies is difficult, however, because some groups report sleep times, others bedtimes. Assessment of self-reported bedtimes instead of sleep times, as done in our study and in many experimental studies, has the advantage that it bypasses the problem of sleep misperception. This might explain why the mean HBD difference between weekday (7.6h) and weekend (9.1h) was a bit larger in our sample compared to the sleep times reported by Breslau et al. (6.6h on weekdays, 7.4h on weekends) or by the 2003 US survey (6.9h on weekdays, 7.5h on weekends) [28].

Several findings support the use of weekend catch-up sleep as a measure of sleep. First, while the association between daytime sleepiness and duration/timing of habitual bedrest as well as sleep debt and social jetlag was generally weak, weekend catch-up sleep (i.e. sleep debt) appeared to exhibit the strongest correlation with the ESS, and was the only measure independently associated with higher ESS scores. Second, participants with ≥2h weekend catch-up sleep rated their habitual sleep efficiency higher than participants with ≤1h weekend catch-up sleep. This feature reveals their increased pressure for sleep, which is reminiscent of the 98-100% sleep efficiency in the polysomnography of many patients with the insufficient sleep syndrome. Third, younger age was the strongest predictor of longer weekend catch-up sleep, a finding that is supported by solid evidence from other studies [15], and may be explained by changes in lifestyle and age-related decrease in biological sleep need [29]. However, while substantial weekend bedtime delays are typical for adolescents, homeostatic influences seemed to outweigh circadian changes in our cohort. Compared to weekday bedtimes, participants with and without sleep debt only moderately delayed their bedtimes during weekends. Significant sleep curtailment during weekdays occurred from both ends (later bedtimes, earlier getting up times), and weekend catch-up sleep resulted mainly from delaying getting-up times.

Despite the independent association between sleep debt and self-reported daytime sleepiness, the absence of the latter in the majority (79%) of participants with relevant sleep debt is one of the most important and intriguing finding of the present study. Nathaniel Kleitman, who first had introduced the term "sleep debt", suggested that people with weekend catch-up sleep but no daytime sleepiness were able to "liquidate the debt" [30]. A recent work showed that two nights of extended weekend sleep may allow reversing the impact of one week of mild sleep restriction (6h/night) on daytime sleepiness, but not on performance deficits [31]. Likewise, another study demonstrated that ad libitum weekend recovery sleep failed to prevent the metabolic consequences of sleep deprivation [32]. Other experimental studies consistently reemphasized a strong dissociation between minimal subjective perception and cumulative deleterious physiological effects of chronic sleep restriction [9, 10, 33]. Thus, the frequent absence of excessive daytime sleepiness in subjects with ≥2h weekend catch-up sleep unlikely reflects successful dissipation of sleep debt, but rather underestimation of, or some adaptation to its consequences. This has also important implications for the management of patients with chronic sleep restriction, and challenges the diagnostic requirement of "*…daily periods of irrepressible need to sleep or daytime lapses into sleep…*" in the current ICSD-3 criteria of the insufficient sleep syndrome. Complete elimination of sleep debt would be necessary, however, if we wished to appreciate its true extent. This is the case when individuals reach asymptotic total sleep times after multiple days with extended sleep opportunity, and people often carry a sleep debt that is too large to get rid of during a single weekend dedicated to maximal sleep [8, 34].

While ≥2h weekend catch-up sleep represents a strong indicator for accumulated sleep loss, we cannot deduce that similar bedtime durations on weekdays and weekends exclude a relevant sleep debt. Habituated to early rising times, the circadian arousal forces on weekend mornings may exceed the residual homeostatic sleep pressure and prevent some people from obtaining sufficient recovery sleep. Thus, the true prevalence of sleep debt in our cohort might be higher than 40%. Indeed, the independent, at first counterintuitive association between longer weekend catch-up sleep and lower BMI offers a differential perspective on the steady alternation between weekday sleep restriction and weekend recovery sleep. This finding, supported by similar emerging evidence in adults and children [17, 35, 36], suggests a protective effect of weekend catch-up sleep, counteracting the detrimental metabolic effects of chronic sleep restriction [37, 38]. A similar beneficial impact of weekend recovery sleep has been shown on arterial hypertension [39, 40].

We also showed that the ESS is a reliable and valid tool to measure daytime sleepiness in participants with and without sleep debt. The ESS had good test-retest reliability, and exhibited only minimal floor and ceiling effects. The reliable distinction between participants with and without sleep debt demonstrated the scale's construct validity. In contrast to the FSS, but in agreement with ESS validation studies in other populations [41, 42], the ESS appeared to have only borderline internal consistency, and factor analysis suggested a two-dimensionality. However, rather than reflecting psychometric limitations of the ESS, these latter findings are explained by the fact that very few participants considered their sleepiness sufficiently severe of dozing also in low soporific situations, as depicted in items 6 and 8. Thus, the cumulative structure of the ESS, with reduced concordance between items with low and high soporific situations, explains the scale's seemingly poor internal consistency and its failure to satisfy the conditions of unidimensionality.

Our study has several limitations. First, although we obtained representative cross-sectional data of a general population sample, the relatively small study cohort hampers generalizability. In addition, the 65% female predominance of the study cohort suggests a participation or inclusion bias. Second, the study does not provide informations on the participants' intake of stimulants such as caffeine or nicotine, or their habits to make daytime naps. Likewise, the study has not adequately controlled for other social factors, including family and work demands as well as number and age of children. Third, we did not include any physiologic or objective sleep-wake measures, to estimate the confounding role of undiagnosed additional sleep disorders (e.g. OSAS, PLMS). Finally, due to its northerly location at 59.9° N latitude, residents of St. Petersburg are exposed to greatly varying day lengths, which may influence their sleep-wake habits and mood [43]. Since 83% of participants responded to our survey during February-March, the risk of seasonal bias is restricted, but future studies should include data with equal distribution over all seasons, in order to appreciate the impact of day length on sleep debt.

In conclusion, sleep debt appeared to be very common in our population-based sample, as indicated by a 40% prevalence of ≥2h weekend catch-up sleep. Our findings suggest two faces of weekend catch-up sleep, with beneficial effects on BMI but increment in daytime sleepiness. In general, subjective symptoms – including various aspects of fatigue, anxiety and depression – are not appropriate to distinguish between varying degrees in sleep debt. The sample's large lack in excessive daytime sleepiness, believed to represent a specific consequence of sleep debt, further highlights that subjective perception is unreliable in detecting sleep debt. By providing evidence of the ESS' reliability and validity, psychometric shortcomings are a less likely explanation of this underestimation. Substantial weekend bedrest prolongation may therefore unmask a relevant sleep debt in patients, who feel alert and believe to obtain sufficient amount of sleep.

Conflict of interest: none

Author contributions

YVG and POV contributed to the conception and design of the study; YVG and YV contributed to the translation and cultural adaptation of the questionnaires; YVG, GGS, EAK and IRG contributed to the acquisition of data; YVG and POV contributed to the statistical analysis, drafting the text and preparing the figures. All authors critically reviewed the final draft of the manuscript.

Abbreviation list

BMI	body mass index
ESS	Epworth Sleepiness Scale
FIS	Fatigue Impact Scale
FSS	Fatigue Severity Scale
HADS	Hospital Anxiety and Depression Scale
HBD	habitual bedtime duration
OSAS	Obstructive sleep apnea syndrome
PLMS	Periodic limb movements during sleep
PSQI	Pittsburgh Sleep Quality Index
UTC	Coordinated Universal Time

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Table 1 Comparison between subjects with relevant and without sleep debt.

	Sleep debt ≥2h	**Sleep debt ≤1h**	***p***
N	103	123	
Age, y	32.7 ± 14.2	44.7 ± 19.8	<0.001
Female sex, n	65 (63%)	82 (67%)	0.68
Body mass index, kg/m^2	23.6 ± 4.0	24.9 ± 4.6	0.02
Education status			0.92
Primary school degree, n	28 (27%)	30 (24%)	
College school degree, n	25 (24%)	30 (24%)	
University degree, n	50 (49%)	61 (50%)	
Marital status			0.04
Single	52 (50%)	48 (39%)	
Married	40 (39%)	58 (47%)	
Divorced	7 (7%)	15 (12%)	
Bedtime characteristics			
Habitual evening bedtime, weekday	00:01 ± 1h12min	23:38 ± 1h15min	0.02
Habitual evening bedtime, weekend	00:51 ± 1h32min	00:22 ± 1h34min	0.02
Weekend delay in evening bedtime	49 ± 67min	44 ± 65min	0.51
Habitual getting up time, weekdays	06:54 ± 51min	07:53 ± 1h19min	<0.001
Habitual getting up time, weekends	10:31 ± 1h30min	09:01 ± 1h47min	<0.001
Weekend delay in getting up time	3h37min ± 1h19min	1h08min ± 1h08min	<0.001
Social jetlag	2h13min ± 1h06min	54min ± 1h05min	<0.001
Habitual bedtime duration on weekdays	6.9 ± 1.2h	8.3 ± 1.0h	<0.001
Habitual bedtime duration on weekends	9.7 ± 1.2h	8.7 ± 1.2h	<0.001
Daytime Vigilance			
Epworth Sleepiness Scale (ESS)	7.5 ± 4.0	5.9 ± 3.6	0.002
Excessive daytime sleepiness (ESS ≥11)	22 (21%)	12 (10%)	0.01
Fatigue Severity Scale (FSS)	3.7 ± 1.3	3.6 ± 1.5	0.79
Fatigue (FSS score ≥4.0)	45 (44%)	50 (41%)	0.69
Fatigue Impact Scale, cognitive	11.4 ± 7.5	9.9 ± 7.5	0.14
Fatigue Impact Scale, physical	10.7 ± 7.7	12.0 ± 8.9	0.27
Fatigue Impact Scale, psychosocial	22.2 ± 12.8	22.8 ± 14.6	0.75
Pittsburgh Sleep Quality Index, (PSQI)			
Subjective sleep quality	1.1 ± 0.6	1.2 ± 0.7	0.43
Sleep latency	1.0 ± 1.0	1.1 ± 0.9	0.41
Sleep duration	1.3 ± 0.8	0.9 ± 0.9	0.001
Habitual sleep efficiency	0.4 ± 0.8	0.7 ± 1.1	0.04
Sleep disturbances	1.3 ± 0.6	1.3 ± 0.6	0.77
Use of sleeping medication	0.3 ± 0.7	0.3 ± 0.8	0.86
Daytime dysfunction	0.9 ± 0.8	0.7 ± 0.7	0.04
Global PSQI score	5.9 ± 2.8	5.9 ± 3.4	0.87
Hospital Anxiety and Depression Scale			
Anxiety subscale	7.7 ± 3.1	7.2 ± 3.1	0.31
Depression subscale	11.4 ± 4.5	11.2 ± 4.6	0.67

Table 2 Reliability statistics and exploratory factor analysis of the Epworth Sleepiness Scale (ESS), obtained from a general population with and without relevant sleep debt. Cronbach's alpha of the total data set was 0.69. Kaiser-Meyer-Olkin test was 0.702, suggesting the ESS data set was suitable for exploratory factor analysis. Bartlett's test of sphericity: χ^2=347.95, p<0.001.

	Epworth Sleepiness Scale	*Reliability statistics*			*Factor structure*		
						Rotated component matrix	
	Items	**Mean±SD**	**Corrected item-total correlation**	**Cronbach's alpha if Item deleted**	**Commu-nalities**	Component 1	Component 2
1	*Sitting and reading* Читая (сидя)	0.85 ± 0.97	0.468	0.638	0.488	0.692	
2	*Watching TV* Смотря телевизор	1.36 ± 1.05	0.392	0.661	0.465	0.681	
3	*Sitting, inactive in a public place (e.g. theater or a meeting)* Спокойно сидя в общественном месте (театр или встреча)	0.45 ± 0.75	0.428	0.651	0.402	0.468	0.427
4	*As a passenger in a car for an hour without a break* В качестве пассажира в автомобиле (>1 часа без перерыва)	1.33 ± 1.06	0.446	0.645	0.413	0.604	
5	*Lying down to rest in the afternoon when circumstances permit* Отдыхая лежа во второй половине дня	1.86 ± 0.98	0.370	0.664	0.447	0.665	
6	*Sitting and talking to someone* Беседуя с кем-либо (сидя)	0.09 ± 0.34	0.284	0.686	0.756		0.869
7	*Sitting quietly after a lunch without alcohol* Сидя после обеда (без употребления спиртного)	0.56 ± 0.81	0.478	0.638	0.477	0.493	0.484
8	*In a car, while stopped for a few minutes in the traffic* В автомобиле, остановившись на несколько минут в пробке	0.09 ± 0.42	0.232	0.689	0.634		0.796

Figure legends

Figure 1

Sleep debt increased with earlier getting up times during weekdays and delayed getting up times during weekends.

Figure 2

Older age was associated with a significant decrease both in sleep debt (A) and in social jetlag (B).

Figure 3

Only 137 participants (53.3%) did not experience either excessive daytime sleepiness (EDS) or fatigue (A); a majority of participants with EDS suffered also from fatigue (63.2%). A relevant sleep debt was most likely to be found in participants with comorbid EDS-fatigue (67%), followed by participants with isolated EDS (43%), without EDS or fatigue (38%), or isolated fatigue (35%) (B).

Figure 4

The scree plots of ESS and FSS demonstrate apparent differences (A). The FSS has only one eigenvalue >1.0, shows a steep decline from the first to the second factor, with a sharp inflexion point and a flat continuation to the last factor. Conversely, the scree plot of the ESS reveals two factors with eigenvalues >1.0 and misses a clear inflexion point. The suggested two-factor structure of the ESS becomes also evident in the component plot (B), with ESS items 6 and 8 loading separately from the remaining items (following extraction by exploratory principle component factor analyses with orthogonal rotation).

Appendix

Table Suppl 1 Multiple linear regression models for coefficients of sleep debt and Epworth Sleepiness Scale (ESS) scores.

Dependent variable	Significant coefficients*	Beta	*t* value	*p*
Sleep debt	Age	-0.232	-3.452	0.001
	ESS score	0.212	3.406	0.001
	Body mass index	-0.132	-1.971	0.050
ESS score	Sleep debt	0.216	3.402	0.001
	Education	-0.146	-2.288	0.020
	HADS anxiety	0.081	2.087	0.040

* The following additional coefficients were included in the model: education status, Hospital Anxiety and Depression Scale (HADS), Pittsburgh Sleep Quality Index (PSQI), and Fatigue Severity Scale (FSS)

Figure 1

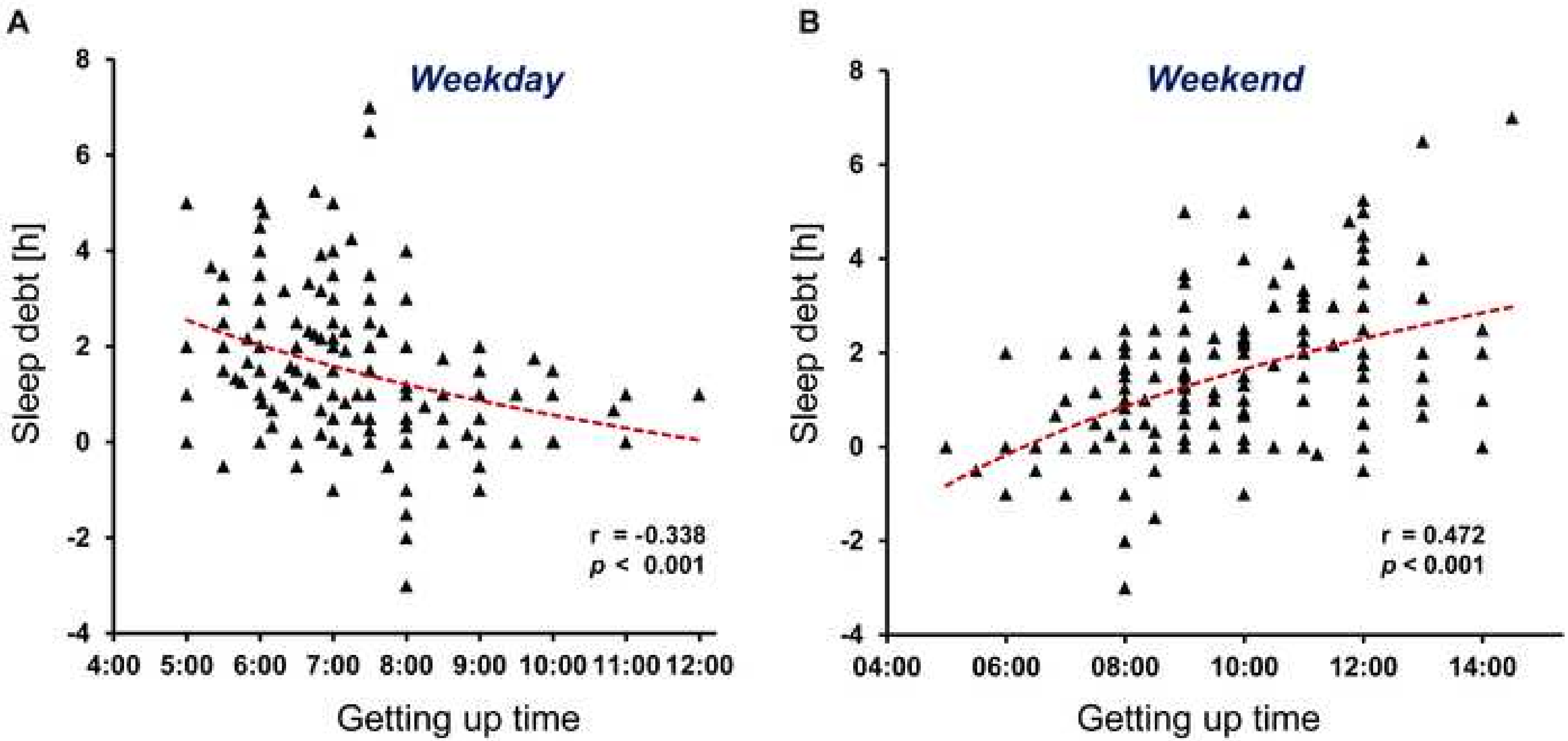

A
Weekday
Sleep debt [h]
8
6
4
2
0
-2
-4
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
Getting up time
r = -0.338
p < 0.001
B
Weekend
Sleep debt [h]
04:00
06:00
08:00
10:00
12:00
14:00
Getting up time
r = 0.472
p < 0.001

Figure 2

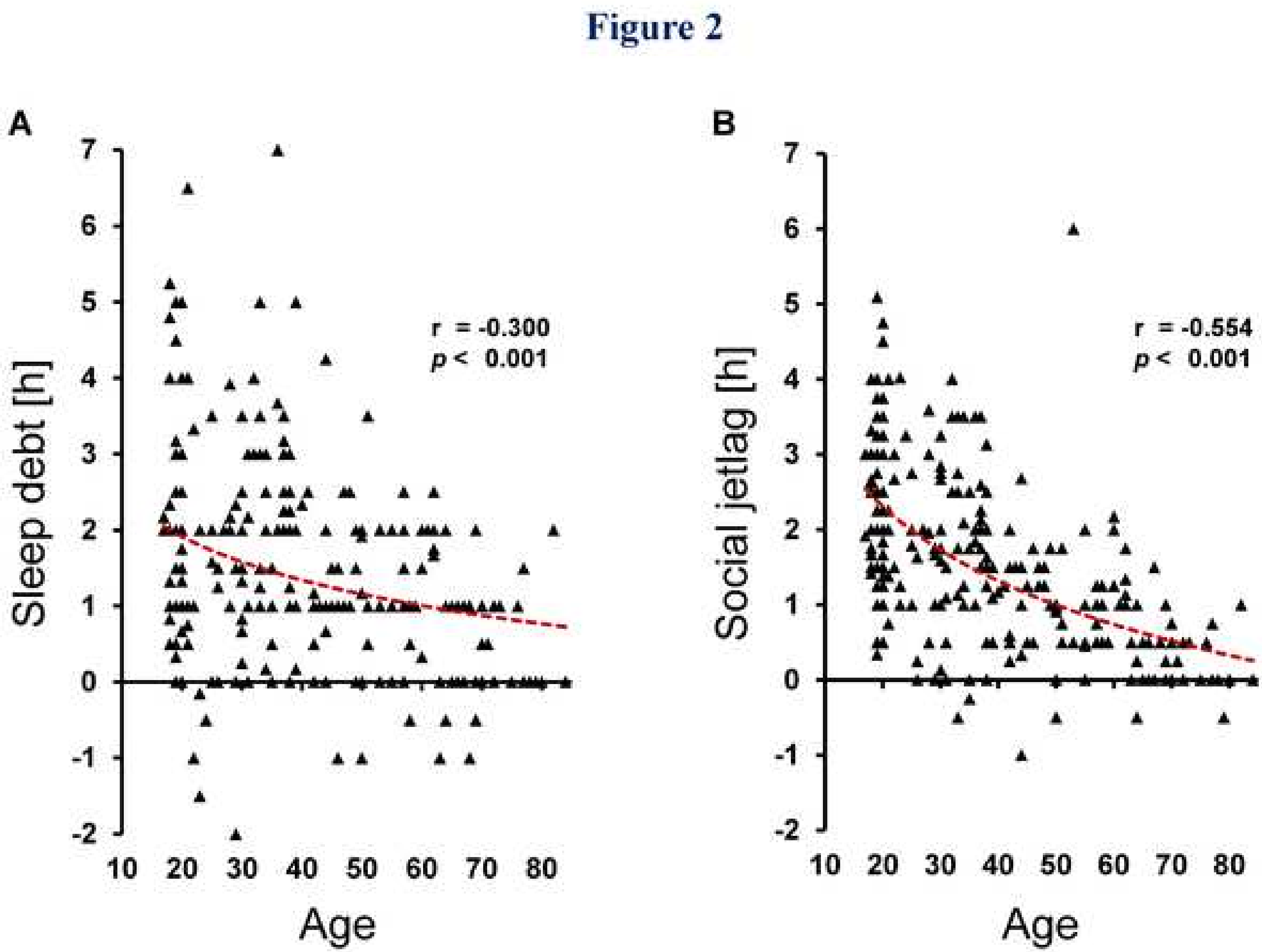


Figure 2
A
Sleep debt [h]
7
6
5
4
3
2
1
0
-1
-2
10 20 30 40 50 60 70 80
Age
r = -0.300
p < 0.001
B
Social jetlag [h]
7
6
5
4
3
2
1
0
-1
-2
10 20 30 40 50 60 70 80
Age
r = -0.554
p < 0.001

Figure 3

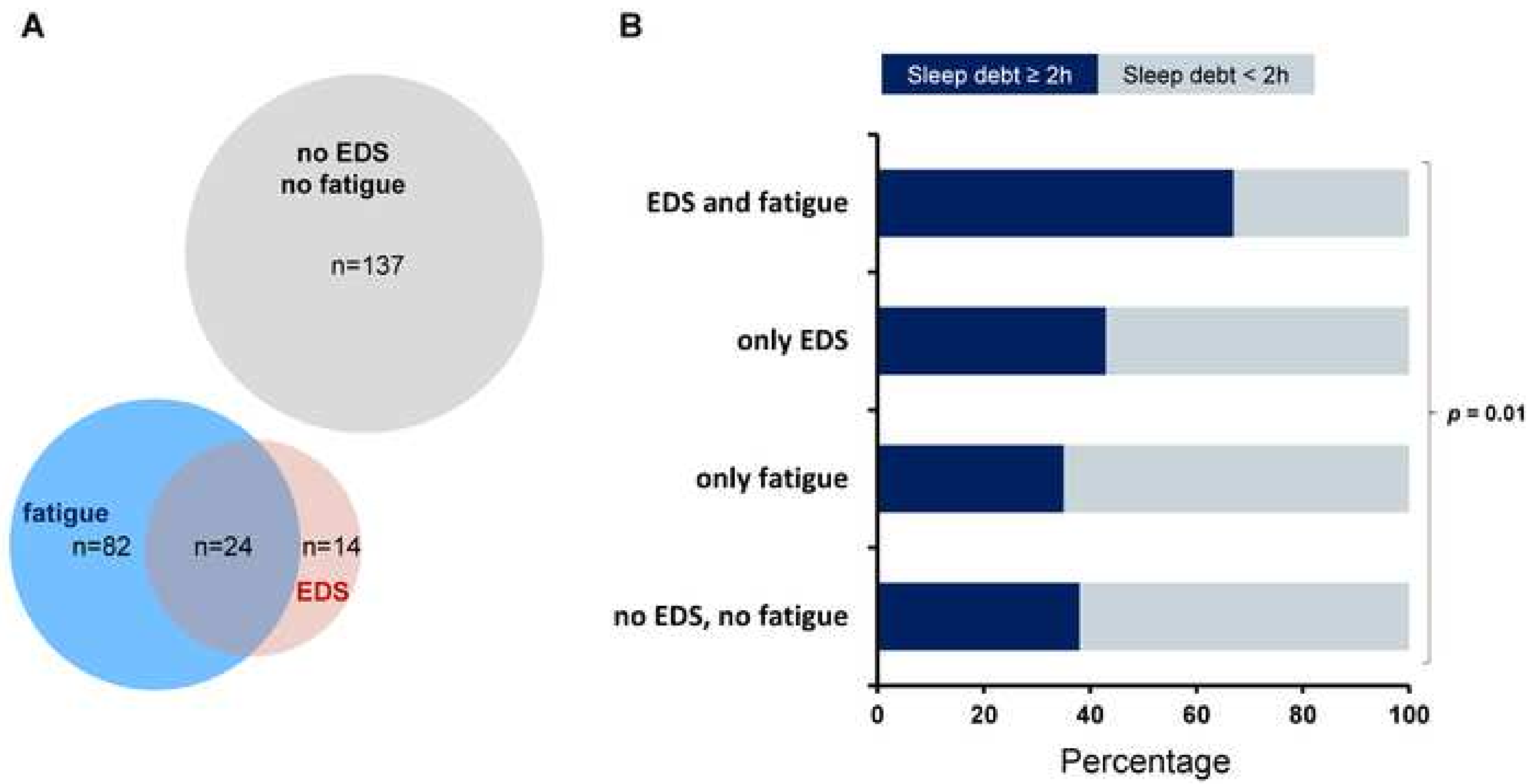
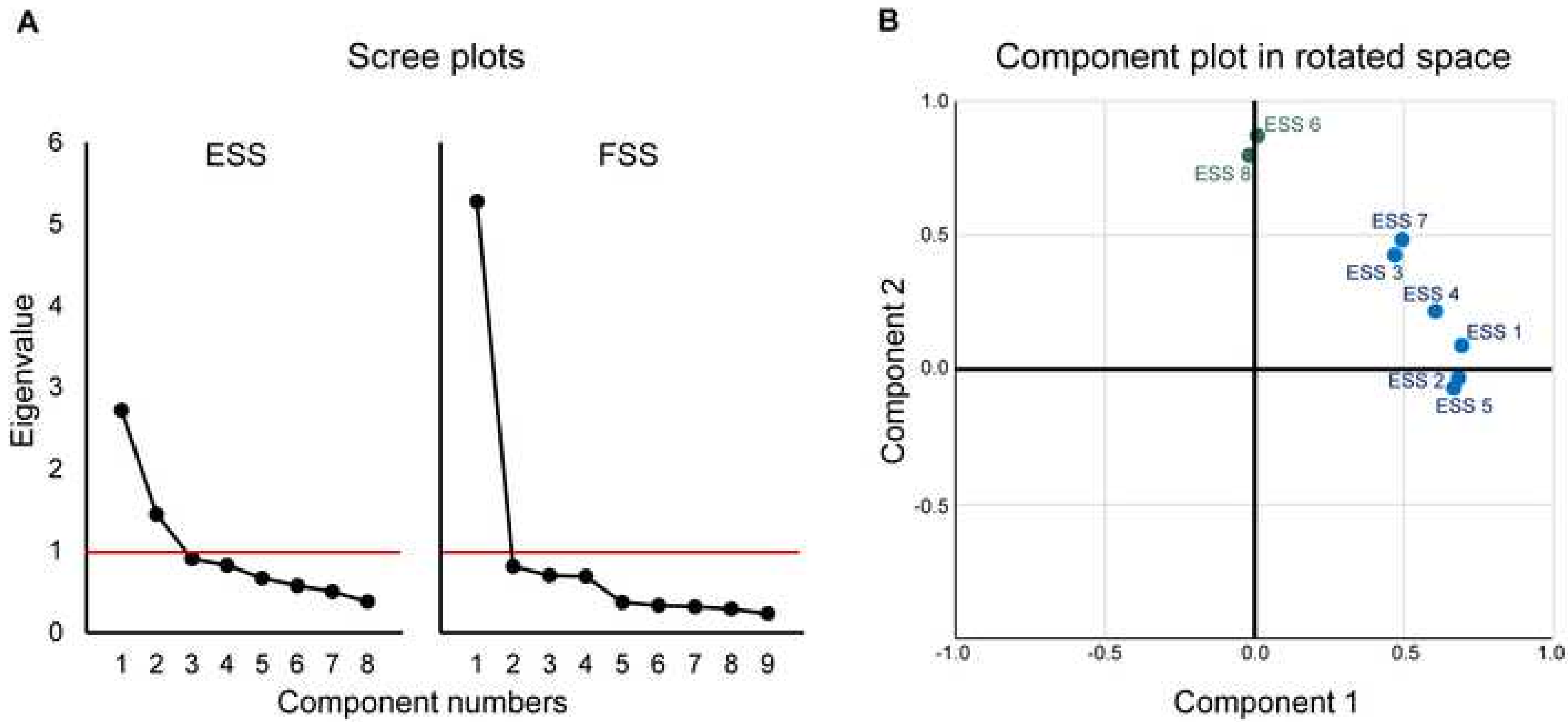

A
no EDS
no fatigue
n=137
fatigue
n=82
n=24
n=14
EDS
B
Sleep debt ≥ 2h
Sleep debt < 2h
EDS and fatigue
only EDS
only fatigue
no EDS, no fatigue
p = 0.01
0
20
40
60
80
100
Percentage

Figure 4



A
Scree plots
ESS
FSS
Eigenvalue
Component numbers
B
Component plot in rotated space
Component 1
Component 2
ESS 6
ESS 8
ESS 7
ESS 3
ESS 4
ESS 1
ESS 2
ESS 5